

Anatomical aspects of the lacrimal gland of the tufted capuchin (*Cebus apella*)

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ABSTRACT

In the tufted capuchin (*Cebus apella*) the main lacrimal gland is composed of 2 distinct portions with an intraorbital and extraorbital localisation, interconnected by a bridge of glandular tissue which crosses the lateral orbital wall through the lateral orbital fissure located in the sphenozygomatic suture. The intraorbital lacrimal gland is flattened and extremely thin, with a variable outline. It lies on the upper and outer third of the globe of the eye, and the aponeurosis and the belly of the lateral rectus muscle, extending antero-posteriorly from the upper lateral angle of the orbit midway along the orbital cavity. The extraorbital lacrimal gland is compact, halfmoon-shaped, with 3 surfaces, 3 borders and 2 extremities. It lies in the temporal fossa between the temporalis muscle and the temporal surface of the zygomatic bone, fitting into a depression in this bone, and totally surrounded by adipose tissue. The secretory cells have a flocculent appearance and either low or high density. They possess a basal region containing the nucleus and rich in granular endoplasmic reticulum, and an apical region filled with secretory granules varying in size, form and density.

INTRODUCTION

Although *Cebus apella* is a simian that is distributed widely in all zoogeographical provinces of Brazil (Coimbra Filho, 1982), it has been little studied either morphologically or physiologically. It is a platyrrhine with the dental formula I 2/2, C 1/1, PM 3/3 and M 3/3, a reduced or rudimentary thumb, flat nails and a prehensile tail (Grassé, 1965). It is a tufted capuchin with either a black or dark brown coat, and a cap on the head composed of long dark erect hairs which may form ridges on either side of the crown (Napier & Napier, 1968).

Few studies have been undertaken on the morphology of the lacrimal gland in monkeys (Bast, 1961; Ruskell, 1968; Marback et al. 1972; Osman Hill, 1972; Machado, 1973; Hirsch-Hoffman, 1976; Gonnering et al. 1984) and the results have been controversial. The purpose of the present study was therefore to investigate the anatomical features of this gland in *Cebus apella*. A preliminary examination by light and electron microscope confirmed its lacrimal nature.

MATERIAL AND METHODS

Preparation for dissection

Adult tufted capuchin monkeys, *Cebus apella* (12 males and 3 females), were sedated by inhalation of chloroform in their cages. After immobilisation in a wooden gutter, the animals were anaesthetised with ketamine hydrochloride (Ketalar, Parke-Davis), 0.5 ml/kg intramuscularly and were then killed by an overdose of ketamine (5 ml/kg) after the intravenous injection of heparin (2000 units).

Under an operating microscope at a magnification of $\times 10$ and $\times 16$, the orbits and the temporal and infratemporal fossae of the 15 heads were dissected on both sides, providing 30 specimens. These heads, fixed in 10% formalin and injected with red Neoprene Latex via the common carotid artery, had previously been decalcified by immersion in 5% nitric acid. Access to the orbit was obtained by removal of its roof through the anterior fossa of the skull and the lateral wall through the temporal and middle fossae. The periorbital tissues were carefully cut to complete visualisation, dissection and analysis of the topographic relations of the lacrimal gland.

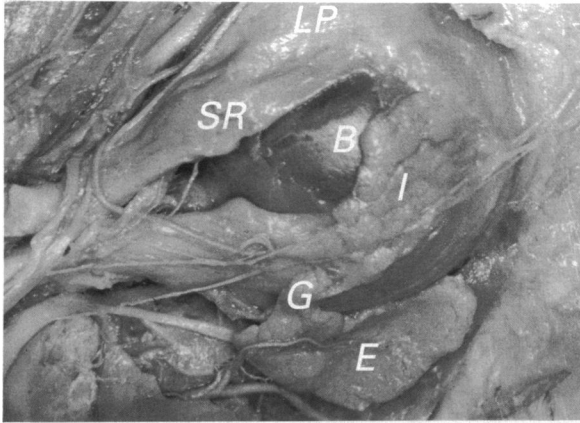


Fig. 1. Monkey 1. Superolateral view of the right orbital cavity after removal of the bony walls and dissection of the temporal and infratemporal fossae. $\times 3.1$. Abbreviations (and for Figs 2–4): *A*, aponeurosis of the lateral rectus muscle; *AB*, adipose body of the orbit; *B*, ocular bulb; *E*, extraorbital lacrimal gland; *F*, external lacrimal fossa; *G*, glandular isthmus; *I*, intraorbital lacrimal gland; *LA*, lacrimal artery; *LF*, lateral orbital fissure; *LN*, lacrimal nerve; *LP*, levator palpebrae superioris muscle; *LR*, lateral rectus muscle; *LWO*, lateral wall of the orbit; *S*, sphenozygomatic suture; *SR*, superior rectus muscle; *V*, belly of the lateral rectus muscle.

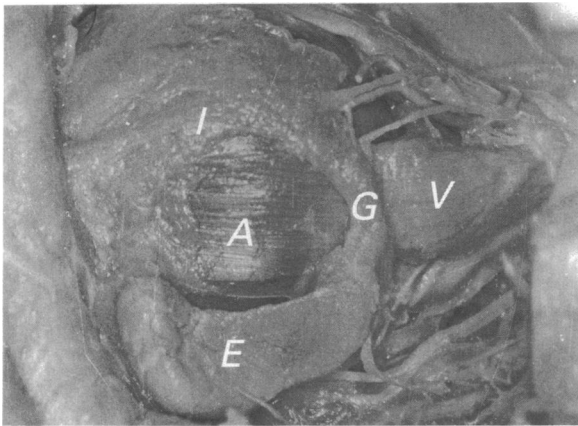


Fig. 2. Monkey 2. Lateral view of the left orbital cavity after removal of the bony walls and dissection of the temporal fossa. $\times 3.3$. For abbreviations, see Fig. 1.

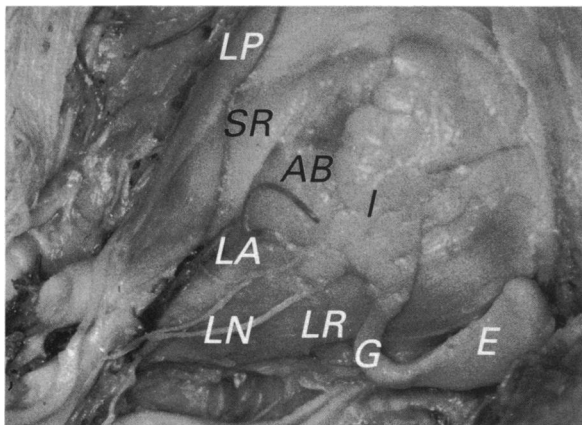


Fig. 3. Monkey 12. Superolateral view of the right orbital cavity after removal of the bony walls and dissection of the temporal and infratemporal fossae. $\times 3.1$. For abbreviations, see Fig. 1.

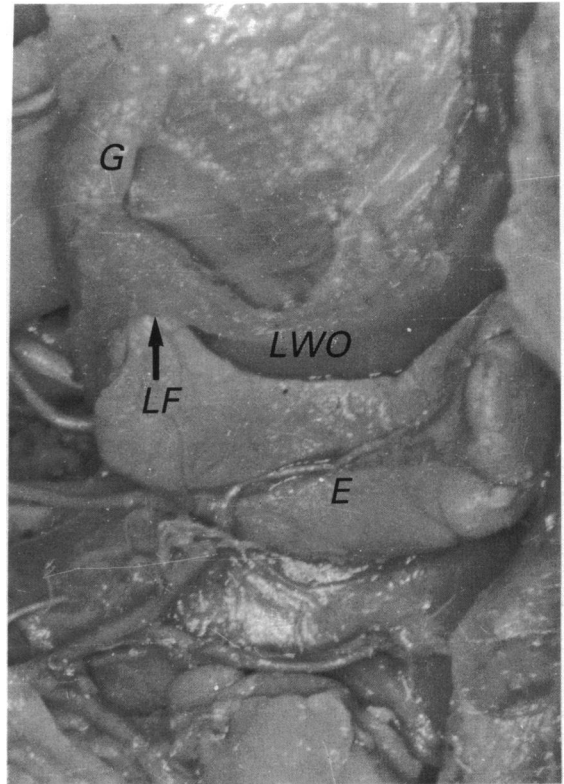


Fig. 4. Monkey 2. Lateral view of the right orbital cavity after partial removal of the lateral bony wall and dissection of the temporal and infratemporal fossae. $\times 5.0$. For abbreviations, see Fig. 1.

Histological procedures

Fragments collected from different parts of the lacrimal gland from 2 additional adult male monkeys were processed for light and electron microscopic examinations. Before fixation of the monkeys by perfusion, sedation and anaesthesia were induced in the same manner as described above, and approximately 2000 units of heparin sodium were injected through a saphenous vein. The common carotid artery was exposed and cannulated and the external jugular vein divided. After exsanguination, the monkeys were perfused with 0.9% sodium chloride in saline through the common carotid artery and fixed and processed as follows: (1) with Bouin's solution and processing by routine histological techniques, the sections being stained with haematoxylin and eosin, and (2) with Karnovsky's solution (1965) and processing by routine techniques, ultrathin sections being examined in a Philips EM-301 electron microscope.

RESULTS

Dissections

In the tufted capuchin the main lacrimal gland is composed of 2 distinct but interconnected portions,

which we have termed the intraorbital and extraorbital lacrimal glands (Figs 1–3) due to their position in relation to the orbital cavity. The intraorbital gland is smaller than the extraorbital lacrimal gland.

The intraorbital lacrimal gland is lamellar, thin throughout its extent and conspicuously lobular. It has a variable form with short expansions that (1) reach the lacrimal artery and nerves on the outer surface of the lateral rectus muscle (Fig. 3), and (2) converge to a small slit in the lateral wall of the orbit (Fig. 4) where the 2 portions of the gland are in continuity via a narrow bridge of glandular tissue, the glandular isthmus (Figs 1–4). The lacrimal ducts for this portion of the gland are difficult to identify even with examination at a magnification of $\times 10$. However, when the upper eyelid is everted, 4–5 apertures of the lacrimal ducts are seen in the outer portion of the superior conjunctival fornix. Anteroposteriorly it extends from the upper lateral angle of the orbit for about half the length of this cavity. Lateromedially it lies on the lateral third of the superior surface of the ocular globe (Fig. 1). This portion of the gland has the following relations. (1) Superiorly it is covered by the orbital fat, the periorbital tissue and the roof of the orbit, respectively. (2) Inferiorly it is supported by the ocular globe in its anterior portion (Fig. 1) and by the aponeurosis and belly of the lateral rectus muscle in its posterior portion (Fig. 2). (3) Its anterior border lies about 2 mm behind the superior border of the orbit and is separated from it by adipose tissue. (4) Its medial border follows the lateral border of the superior rectus and levator palpebrae superioris muscles (Figs 1, 3), separated by a space of about 5 mm filled by orbital adipose tissue (Fig. 3).

The extraorbital lacrimal gland, which is lobulated, is halfmoon-shaped. In cross-section it has a triangular outline with superior, medial and lateral borders and orbital, temporal and inferior surfaces. Its posterior and anterior extremities are situated in the longitudinal axis. The posterior extremity is tapered and continuous with the intraorbital lacrimal gland through a narrow bridge of glandular tissue, the isthmus (Figs 1–4). The anterior extremity, which is superficial, is large and lies separated from the temporal fascia by adipose tissue. This gland fills the anterior and inferior region of the temporal fossa, fitting into a space delimited anteromedially by a depression in the temporal surface of the zygomatic bone, the external lacrimal fossa (Figs 5, 6), and posterolaterally by the temporalis muscle. In this space the gland lies external to the lateral wall of the orbit (Fig. 4), surrounded by adipose tissue. Its length – the longitudinal axis – varies from 18 to 22 mm and

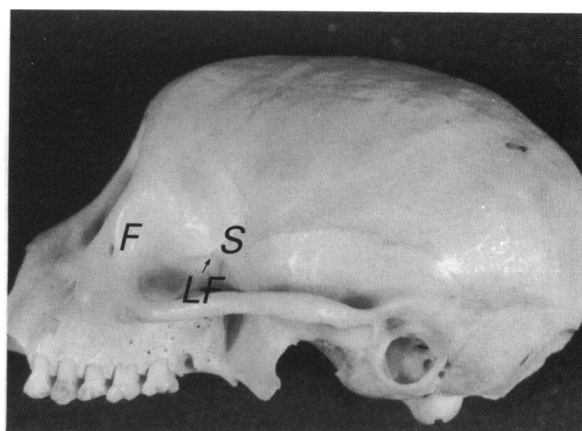


Fig. 5. Lateral view of the skull of *Cebus apella*. $\times 1.0$. F, external lacrimal fossa; LF, lateral orbital fissure; S, sphenozygomatic suture.

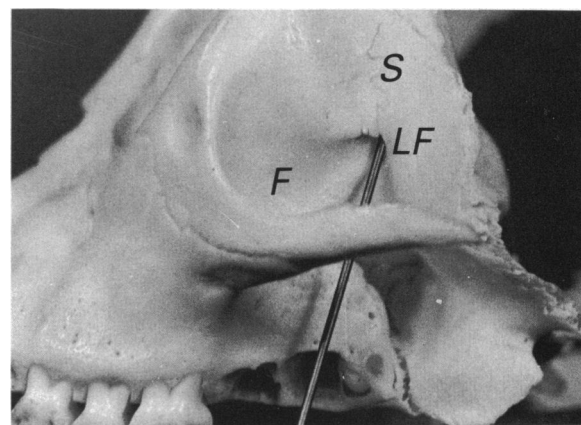


Fig. 6. Lateral view of the skull of *Cebus apella* at higher magnification. The lateral orbital fissure (LF) is crossed by a sound. $\times 2.2$. F, external lacrimal fossa; S, sphenozygomatic suture.

its surfaces vary in width from 5 to 7 mm in the largest intermediate region. The excretory ducts of this portion of the gland are contained in the glandular isthmus. They cross the parenchyma of the intraorbital lacrimal gland and reach the conjunctival sac.

The glandular isthmus which connects the 2 portions of the main lacrimal gland is constituted by (1) glandular parenchyma, (2) the excretory ducts of the extraorbital gland and (3) branches of the lacrimal artery and nerve. It crosses a cleft, the lateral orbital fissure (Figs 4–6), located in the sphenozygomatic suture (Figs 5, 6), communicating between the orbital cavity and the temporal fossa.

Histological observations

The intraorbital and extraorbital lacrimal glands show the same histological characteristics when examined by light microscopy. Both are tubulo-acinous with predominantly serous secretory cells. These cells have

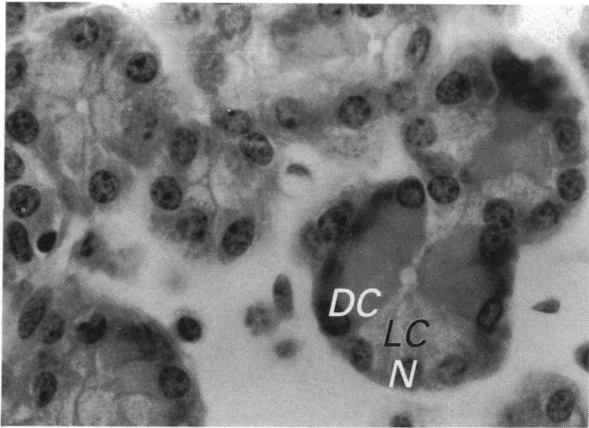


Fig. 7. Extraorbital lacrimal gland of *Cebus apella*. Haematoxylin and eosin. $\times 1000$. DC, dark cell; LC, light cell.

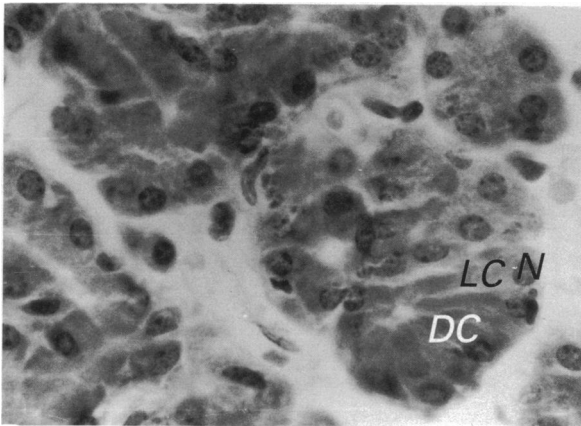


Fig. 8. Intraorbital lacrimal gland of *Cebus apella*. Haematoxylin and eosin. $\times 1100$. DC, dark cell; LC, light cell; N, nucleus.

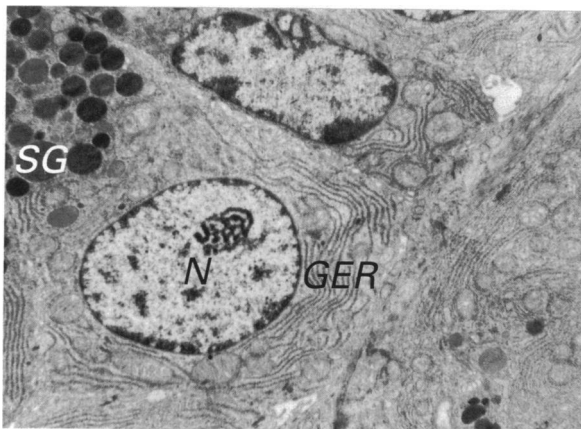


Fig. 9. Secretory cell of the extraorbital lacrimal gland of *Cebus apella*. $\times 6400$. GER, granular endoplasmic reticulum; N, nucleus; SG, secretory granule.

either a pyramidal or cylindrical shape with a spherical nucleus located in a basal position. The supranuclear cytoplasm has a flocculent appearance, having either low density (light cell) or high density (dark cell) (Figs 7, 8).

On electron microscopy the intraorbital and extra-

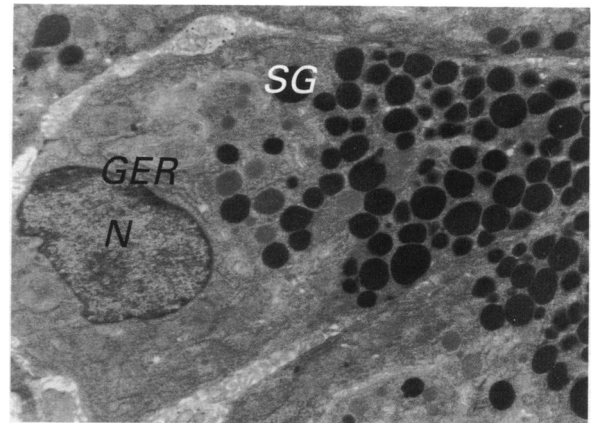


Fig. 10. Secretory cell of the intraorbital lacrimal gland of *Cebus apella*. $\times 5100$. N, nucleus; GER, granular endoplasmic reticulum; SG, secretory granule.

orbital lacrimal glands show acini with either pyramidal or cylindrical cells with a distinct polarity. The basal region contains a round or oval nucleus and an abundant granular endoplasmic reticulum. The supranuclear region is filled with secretory granules varying in size, form and density (Figs 9, 10). The narrow apical portions of these cells delimit a small lumen and present several microvilli.

DISCUSSION

It surprised us to find that in the tufted capuchin the main lacrimal gland has 2 distinct portions, with intraorbital and extraorbital components. The reason for our surprise was that so far an extraorbital lacrimal gland has only been described in rodents (Schmidt, 1959; Benson, 1964; Kronman et al. 1968; Pospíšilová & Dvůrák, 1972; Coujard, 1974; Nikkinen et al. 1985), and not in primates. However, Rochon-Duvigneaud (1954) called attention to the fact that many mammals possess extraorbital glands derived from the conjunctival sac, into which their excretory ducts open, not specifying whether they are lacrimal or harderian glands.

The intraorbital lacrimal gland of *Cebus apella* is extremely thin, flattened, small and with a variable form. These features are not observed in *Macaca mulatta* (Bast, 1961), nor in *Callithrix jacchus* (Marback et al. 1972). However, in *Lagothrix* sp. it is flattened, egg-shaped and 20 mm long (Osman Hill, 1972). A lobulated appearance has also been described in the rhesus monkey (Bast, 1961), in the palpebral lobe in man (Duke-Elder, 1961; Wolff, 1968; Kuhnel, 1968b; Gardner et al. 1978; Ham & Cormack, 1983) and in the cynomolgus monkey (Gonnering et al. 1984). This lobulation is absent in *Cebus* monkeys,

genus *Lagothrix*, in which the gland is smooth (Osman Hill, 1972).

The location of the intraorbital lacrimal gland of *Cebus apella* differs from that illustrated for the rhesus monkey, where it is confined to the superolateral angle of the orbit (Bast, 1961). In the marmoset it is located on the superior temporal side of the eye (Marback et al. 1972). In monkeys of the family Cebidae, genus *Lagothrix*, it occupies the major part of the orbital outlet superiorly (Osman Hill, 1972) and according to Gonnering et al. (1984), in cynomolgus monkeys it extends from the inferior orbital fissure to the lateral wall, where its lobules occupy the superolateral part of the orbit.

The topographic relationship of the intraorbital lacrimal gland of *Cebus apella* with the lateral rectus and superior rectus muscles is not mentioned for the lacrimal glands of the monkeys from genus *Lagothrix* (Osman Hill, 1972). In man (Duke-Elder, 1961; Wolff, 1968; Gardner et al. 1978; Ham & Cormack, 1983) it lies superficial to the levator palpebrae superioris.

The extraorbital lacrimal gland found in *Cebus apella* has not yet been described in other primates. This requires further investigation. In addition to the authors already cited, an extraorbital lacrimal gland was not reported by Schwartz & Huelke (1963), who dissected under a binocular microscope the masticatory muscles of macaque monkeys, nor by Gasser & Wise (1972), who described the temporal and infratemporal fossae of the baboon (*Papio cynocephalus*), or by Madeira & de Oliveira (1979), who described the temporalis muscle and the temporal and infratemporal fossae of the *Cebus apella*. In the cynomolgus monkey, on the other hand, Gonnering et al. (1984) found lacrimal gland tissue passing through the inferior orbital fissure towards the infratemporal fossa.

The anatomical features of the extraorbital lacrimal gland of *Cebus apella*, such as size, shape, site and relationships differ from those found for the extraorbital lacrimal gland of the rat (Schmidt, 1959; Benson, 1964; Coujard, 1974).

In *Cebus apella* the ducts of the extraorbital lacrimal gland are contained in the glandular isthmus; they cross the parenchyma of the intraorbital lacrimal gland and reach the conjunctival sac. In white rats the excretory duct from the extraorbital lacrimal gland joins the duct of the intraorbital lacrimal gland and this single duct reaches the conjunctival sac (Schmidt, 1959).

The lateral orbital fissure present in *Cebus apella*, crossed by the isthmus of the gland, is referred to by

HersHKovitz (1974) as a relic of the primitive orbito-temporal opening which existed in ancestral simians, being present in platyrrhines and either vestigial or absent in living catarrhines.

The classification of the intraorbital and extraorbital lacrimal glands of *Cebus apella* into tubulo-acinous and predominantly serous follows Ham & Cormack (1983) and Junqueira & Carneiro (1985) for the human lacrimal gland. The secretory cells present, with respect to their shape and the position of the nuclei, have the same characteristics as described by Schmidt (1959) and Coujard (1974) in the extraorbital lacrimal gland of the white rat, Marback et al. (1972) in the marmoset, Machado (1973) in the accessory lacrimal gland in Cebidae, Hirsch-Hoffmann (1976) in the rhesus monkey, and Ham & Cormack (1983) and Junqueira & Carneiro (1985) in man. The flocculent nature of the cytoplasm was noted by Allen et al. (1972) in man. The presence of light and dark cells also was recorded by Marback et al. (1972) in the marmoset, Hirsch-Hoffmann (1976) in the rhesus monkey, and Egeberg & Jensen (1969), Orlandini et al. (1970), Orzalesi et al. (1971) and Weingeist (1973) in man.

The ultrastructural features of the secretory cells of the intraorbital and extraorbital lacrimal glands of *Cebus apella* are identical. The abundant granular endoplasmic reticulum in the basal region, and numerous secretory granules of varying size, shape and density in the apical region were also observed in rats by Scott & Pease (1959) and Ichikawa & Nakajima (1962), in dogs by Kuhnel (1968a), in macaque monkeys by Ruskell (1968) and Hirsch-Hoffmann (1976), and in man by Kuhnel (1968b), Egeberg & Jensen (1969), Orlandini et al. (1970), Orzalesi et al. (1971), Weingeist (1973) and Ruskell (1975).

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